石英玻璃光固化 3D 打印制造技术的研究

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石英玻璃具有硬度大、耐高温，热膨胀系数低，化学稳定性与电绝缘性好，可见光波段光学透过率高等特点，已经成为了现代科学研究与工业中不可或缺的重要材料。但由于石英玻璃的硬脆性，诸如热成型、机械加工等传统的加工方法, 难以成型半导体芯片、微流控芯片、光纤与光学器件等功能器件，只能制造简单结构，且加工效率低，成本高，这些缺点制约了石英玻璃的应用范围。而光固化增材制造技术能够快速成型复杂结构，且无需复杂的二次加工与模具，并且成型后的模型打印精度高，表面质量好，与热处理结合可用于玻璃、陶瓷等工程材料的成型，具有良好的应用前景。目前的石英玻璃光固化打印仍然处于研究阶段，制造的玻璃与商用的石英玻璃仍然存在一定的差距，存在着光学透过率低、容易出现微裂纹与层状开裂等问题。本研究通过对石英玻璃增材制造的关键技术——高固含量且低粘度二氧化硅浆料的制备、光固化打印过程与热处理工艺进行优化，制备出无裂纹致密非晶的石英玻璃样品。在此基础上尝试进行了诸如个性化玻璃饰品、微流控芯片、复杂结构光纤预制棒等结构的打印尝试，初步验证了这项技术的优势与广阔的应用前景。

关键词：增材制造；石英玻璃；光固化；复杂结构

ABSTRACT

Silicon glass is an indispensable material in modern scientific research and industry, because of its advantages such as high hardness, high temperature resistance, low thermal expansion coefficient, good chemical stability and electrical insulation. Due to its high melting temperature and the characteristics of hard brittle materials, it is difficult to form functional devices with complex structures such as semiconductor chips, microfluidic chips, optical fibers and optical devices through traditional processes such as thermoforming and mechanical processing， which can only manufacture simple structures with low efficiency and high cost. These shortcomings restrict the large-scale application of silica glass. While the photocuring additive manufacturing technology can rapidly form complex structures without complex secondary processing and molds, the formed models have meanwhile high printing accuracy and good surface quality. Combined with heat treatment, engineering materials such as glass and ceramics can be molded, which has a good application prospect. At present, the photocuring printing of silicon glass is still in the research stage, and there is a certain gap between the manufactured glass, which has lower optical transmittance, prone to microcracks and layered cracks, and commercial silicon glass. In this study, by optimizing the key technologies of additive manufacturing of silicon glass such as high-solid content and low-viscosity slurry, the photocuring printing process and the heat treatment process, a dense amorphous silicon glass without cracks was formed. Based on this research, personalized glass ornaments, microfluidic chips, and optical fiber preforms with complex structures was printed, which preliminarily verified the advantages and broad application prospects of this technology.